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PRELIMINARY TESTS ON A GRP-VINYL FOAM SANDWICH COMPRESSION PANE--ETC(U)
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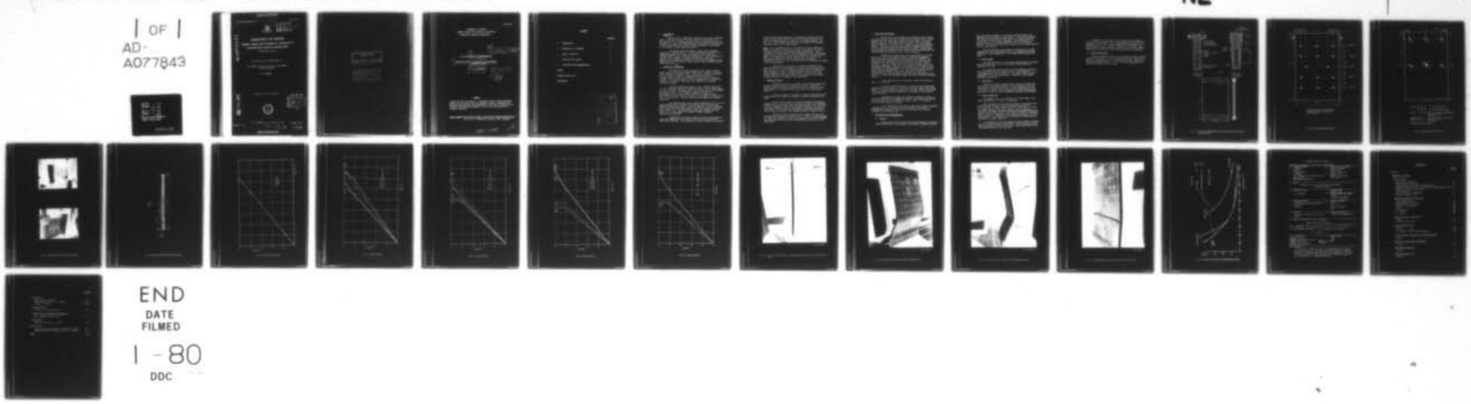

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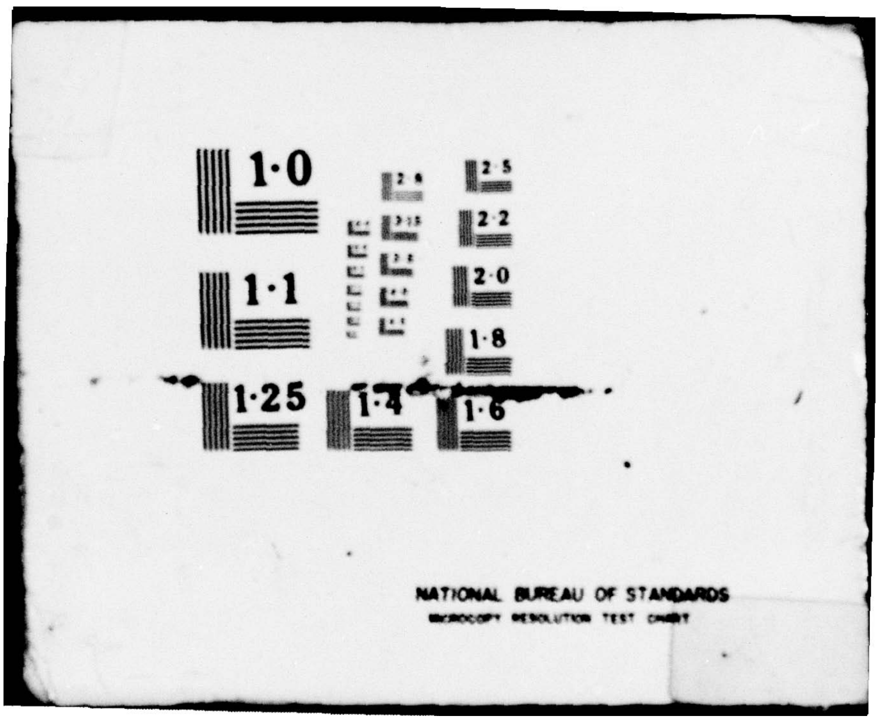
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Structures Technical Memorandum 282

# PRELIMINARY TESTS ON A GRP-VINYL FOAM SANDWICH COMPRESSION PANEL

P.H. TOWNSHEND

Approved for Public Release.







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(10) P.H. TOWNSHEND

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## SUMMARY


A series of tests were made on a compression panel of glass reinforced plastic and rigid vinyl foam core sandwich in order to determine the behaviour and establish testing methods for this type of structure which the Royal Australian Navy proposes to use for the construction of a catamaran minehunter.



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## 1. INTRODUCTION

Design data on commercially available glass fibre reinforced plastic (GRP) was required to form the basis for the design of the hull structure for a catamaran minehunter for the Royal Australian Navy. Assistance in testing was requested by Materials Research Laboratories in those areas where their facilities were inadequate as for example in the testing of large compression panels.

Preliminary tests were made on a panel of GRP sandwich construction, prepared by MRL, in order to determine the behaviour of compression panels of this type, the effects of end conditions, suitable types of strain gauges and adhesives etc., before embarking on the main test programme. It should be noted that while some experience has already been gained in the testing of GRP materials and composites little work has been done at ARL on large compression panels of this material.

## 2. DESCRIPTION OF SPECIMEN

GRP sandwich structure consists of outer layers of glass cloth, woven rovings and/or random oriented fibre (chopped strand mat) bonded together by polyester resin. Those outer layers are separated by a core material such as a low density foam which serves to transmit loads to support and stabilise the skins against premature buckling. The obvious purpose of this arrangement is to increase the rigidity and strength of the glass cloth layers with a minimum increase in weight.

The panel supplied was made up from a rigid PVC foam core of 20 mm. thickness sandwiched between two skins of GRP of approximately 7 mm. thickness. The panel was laid up by hand and the GRP consisted of alternate layers of 300 gm/metre$^2$ chopped strand mat and 800 gm/metre$^2$ woven rovings bonded together with polyester resin. There were four layers of woven rovings and five layers of chopped strand mat to each GRP skin - the skin starting and finishing with chopped strand mat.

The completed panel was of overall dimensions 130 cm. x 84 cm., these dimensions were dictated by the limitations of the machining capacity of the ARL jig borer. The panel ends were locally reinforced by two aluminium alloy bars bonded to, and bolted through, the panel as shown in Fig. 1(a). The foam core had also been replaced over the first 6 cm. of panel depth by a length of timber to provide additional end stiffness.

Subsequently, at an early stage in the tests, the aluminium alloy bars separated from the ends of the panel and a significant modification was made. This consisted of locally doubling the thickness

of the GRP skins and tapering off the doublers to diffuse the load evenly into the skins followed by casting the ends of the panel in a chocking compound between the platens of the testing machine. See Fig. 1(b). This ensured that the ends of the panel were compatible with the platens of the testing machine.

<u>NOTE</u>: It is standard practice in the testing of large compression panels of aircraft structure for the ends of the panel to be cast in low melting point alloy and machined square and parallel. This stabilises the loaded edges of the panel preventing local overloading, buckling and collapse and ensures even diffusion of the load into the panel. Low, melting point alloy (melting port circa $100^{o}$ C) was obviously unsuitable for GRP and an epoxy chocking compound (Epirez 403) was used to cast the panel ends in situ between the platens of the testing machine.

The flatness of the panel was checked by supporting the panel horizontally on three supports of equal height marking off the panel into a 10 cm. grid and measuring heights by dial indicators at grid intersection points. The panel was then turned over and the process repeated. Deviations from flatness of up to 1.5 mm. were found. These deviations are probably quite significant but must be accepted because of the hand laid up construction.

## 3. METHOD OF TESTING

The panel was set up in the ARL 2.65 MN testing machine and aligned carefully between the compression platens. Deflection measuring indicators were placed on each side of the panel to ensure even loading and to measure any relative rotation of the machine platens.

Loads were applied to the panel in equal load increments and corresponding strain gauge and deflection readings recorded at each stage.

In the initial stages of testing horizontally mounted dial gauges placed in five rows across the panel were used in an endeavour to detect incipient buckling but these gauges proved to be too erratic with poor repeatability and it was decided to dispense with them in later tests. The two vertical dial gauges however were retained and used throughout the tests. Dial gauges stations are shown in Fig. 2.

Twelve electrical resistance strain gauges (six per side) were bonded to the panel as shown in Fig. 3. Later, two further gauges of longer gauge length viz 20 mm. were attached at the centre position and proved to be more consistent and repeatable than those of 6 mm. gauge length.

## 4. TESTS AND TEST RESULTS

Several trial runs were made up to loads of 60 kN to check the load distribution across the panel and during these runs it became apparent from the strain gauge readings that the edges of the panel were not parallel transversely across the edges. This was probably caused by bending of the panel by the clamps used during the machining process. The ends of the panel were therefore shimmed progressively until the load distribution was even across the panel. During these initial stages the aluminium alloy reinforcing bars became detached and the modifications described in Para. 3 were introduced.

Testing was continued and two runs were made to 100 kN and two runs to 200 kN with strain readings at convenient increments. Finally the panel was loaded until the occurrence of buckling. The panel sustained a maximum load of 503 kN and at this stage buckling occurred in the lower half of the panel as shown in Figs. 4 and 5. The load on the panel dropped off to 110 kN and held this value with increasing compression. The panel was unloaded at this stage when the buckle depth was approximately 6 cm. and the foam core at the crest of the buckle had compressed about 3 mm. The panel was removed from the testing machine and over 24 hours the panel and the foam core recovered and the final permanent buckle depth was approximately 2 mm. See Fig. 11. Mean vertical deflections of the panel are shown graphically in Fig. 6.

Strain gauge readings are plotted in back to back pairs on Figs. 7, 8, 9 and 10.

It will be noted that there is a deviation from linear with the majority of the gauges at around 400 kN and that back to back gauges deviate in opposite directions indicating increasing tension on one side of the panel and increasing compression on the other at this buckling stage of the test.

Subsequently the panel was reloaded to produce a failure in the fibre glass skins and compression failure of the fibreglass occurred in the concave side of the buckles as shown in Figs. 12, 13 and 14 45 cm from the bottom of the panel.

It is interesting to note that in this test the panel sustained a maximum load of 230 kN before the load started to fall away, a considerable increase over the load of 110 kN in the fully buckled condition of the previous test.

## 5. CONCLUSIONS AND RECOMMENDATIONS

### 5.1 General

These preliminary tests have fulfilled the purpose of providing valuable experience in the testing of GRP sandwich compression panels

and a more ready acceptance of the wider tolerances used in the manufacture of structures of this material. It has been determined that the accurately machined loaded ends of the panel (which was a limitation on panel overall dimensions) are unnecessary as the ends can be set in a chocking compound in situ in the testing machine. Thus the only limitation on panel size is the load capacity of the testing machine.

With the relatively lower modulus of elasticity of the GRP compared with steel and aluminium alloy test personnel must become accustomed to the accommodation of such larger deflections during tests.

5.2 Strain gauges

The inconsistencies in strain gauge readings which are evident from the graphs Figs. 7-10 are attributed to the variability in thickness of the GRP.

More extensive strain gauging will be necessary in future in order to provide a better overall picture of panel behaviour. It is recommended that strain gauges of 20 mm. gauge length be used in preference to the 6 mm. gauge length. Otherwise, strain gauges performed satisfactorily.

5.3 Deflections

Vertical deflection readings showed virtually no deviation from linearity and proved valuable in the monitoring of even load distribution across the panel and the overall compressive strain of the panel. However, the horizontal dial gauges provided little meaningful information behaved erratically and were non-repeatable.

5.4 Buckling behaviour

The degree of restraint imposed on the loaded edges of the panel approximates to a "built in" condition.

The calculated critical buckling stress for this panel from the Euler strut equation (using the Swedish Navy Value for E = 10,000 MPa) is 44 MPa compared with the actual value of 43 MPa. The buckle pattern of the panel, however, was not strictly in accordance with Euler because the ends were not rigidly constrained against rotation and rotation of the ends was observed with dropping away of the load. Compression of the foam core of about 4 mm. was also observed. This indicates that the buckling strength might be improved by a stiffer foam core.

The behaviour of the panel could have been adversely affected by the irregularities due to hand lay-up. This panel with a 20 mm. foam core could well be more sensitive to these irregularities than the proposed panel with a 60 mm. core.

The Euler curve for built-in end conditions is plotted on Fig. 15 and the test panel with a high slenderness ratio shows good agreement with the curve. Small compression test specimens with a slenderness ratio of 7.5 failed in compression at 180 MPa. The Euler curve for simply supported ends is also shown with estimated Swedish Navy results for a 60 mm. foam core and 12 mm. GRP skin.

### 5.5 Further developments

Tests on compression panels of the proposed sandwich construction for "Minehunter" i.e. 8 mm. GRP skins and 60 mm. foam will be tested in a similar manner to the Swedish Navy tests. These tests were made on panels 800 mm. x 300 mm. with simply supported end conditions simulated by knife edges.

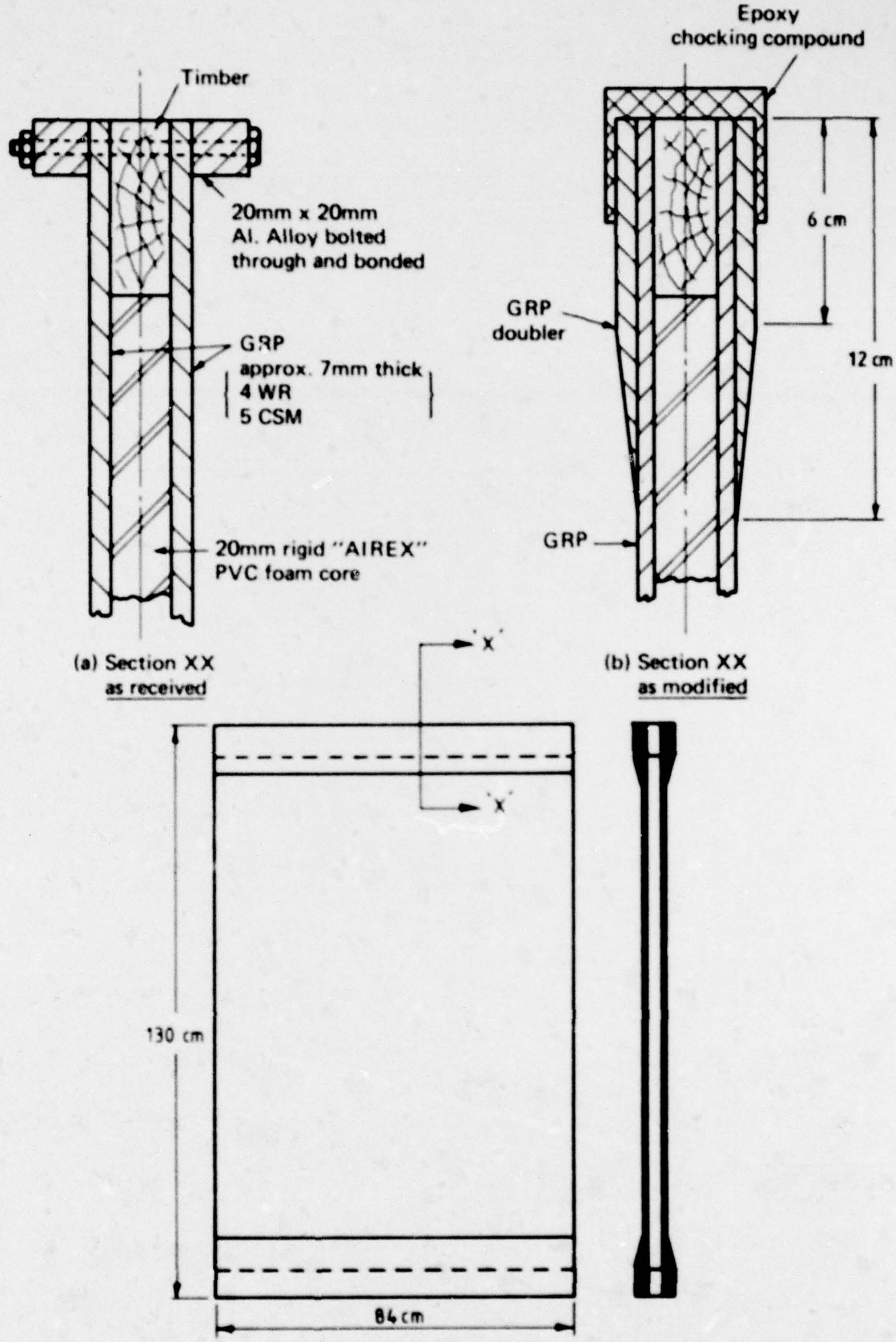
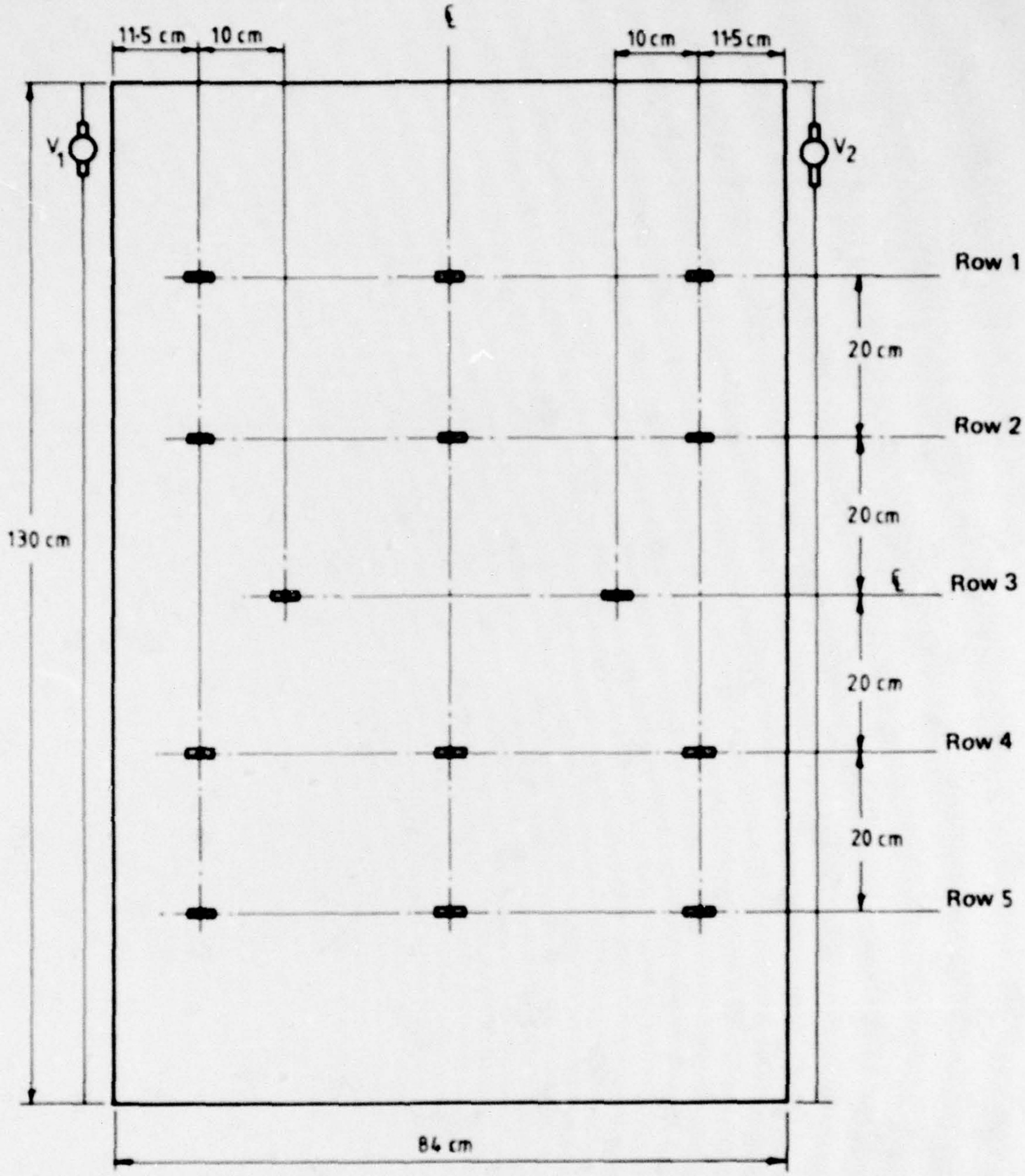
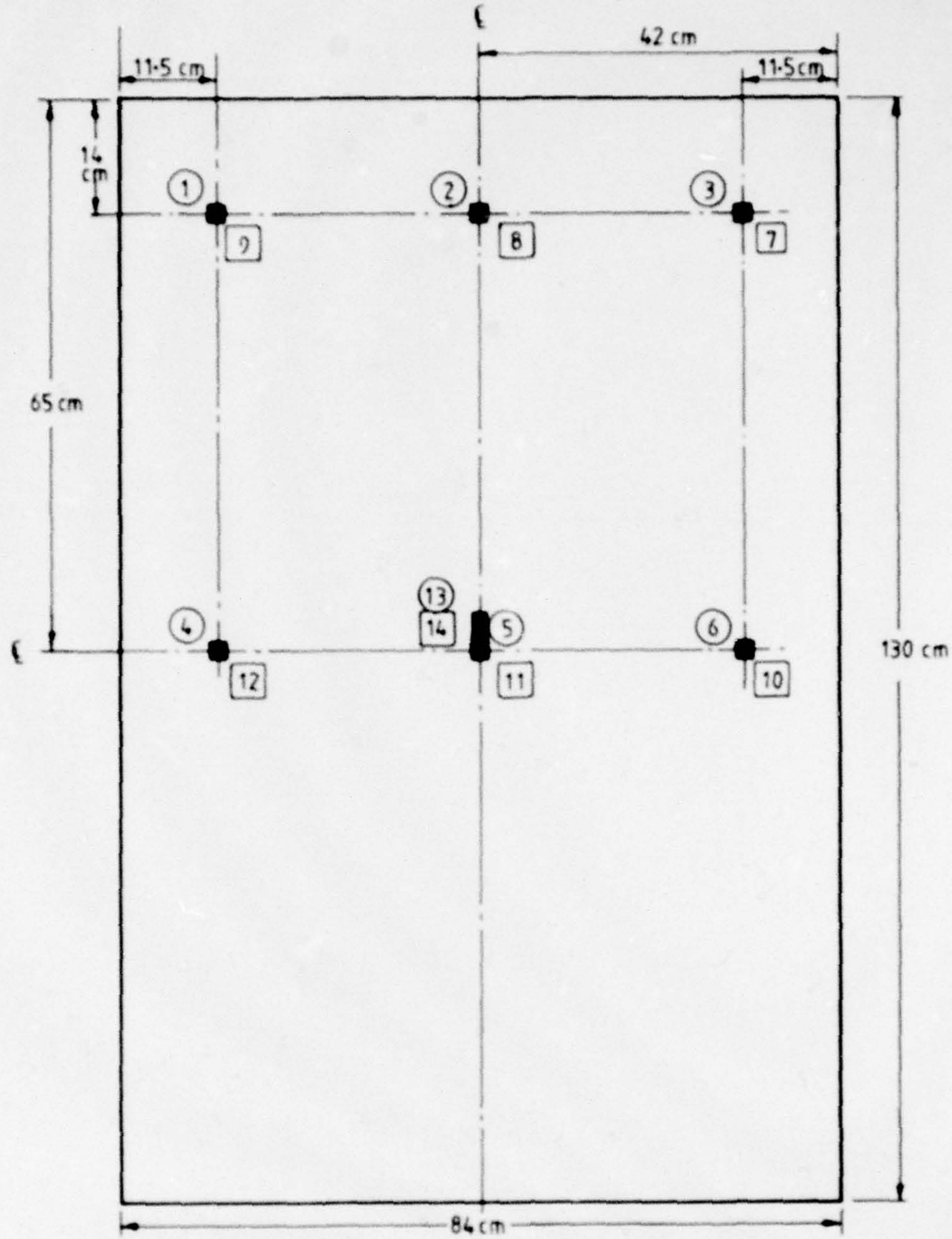



FIG. 1. DETAILS OF COMPRESSION PANEL CONSTRUCTION AND END CONFIGURATION




Indicators $V_1$ and $V_2$: vertical deflection.
All other dial indicators horizontal to
one face of panel.

FIG. 2. DIAL INDICATOR STATIONS




Gauges (1) (2) (3) – etc. on one side of panel.

[7] [8] [9] – etc. on opposite side of panel.

| | |
|---|---|
| Gauges 1 12 inclusive | TML type GFLA-6 (6mm gauge length)<br>Resistance: 120 ohm<br>G.F.: 2.16 |
| Gauges 13 and 14<br>(adjacent to 5 and 11) | Type PL-20-11 (20mm gauge length)<br>Resistance: 12 ohm<br>G.F.: 2.09 |

Adhesive M-Bond 200+ catalyst

FIG. 3. STRAIN GAUGE POSITIONS

FIG. 4. PANEL AFTER FAILURE BY BUCKLING

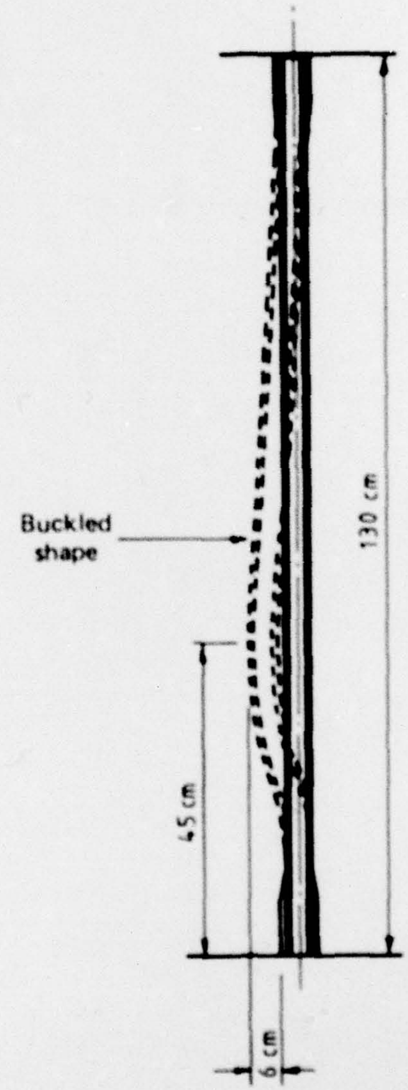



FIG. 5. CONFIGURATION OF BUCKLED PANEL

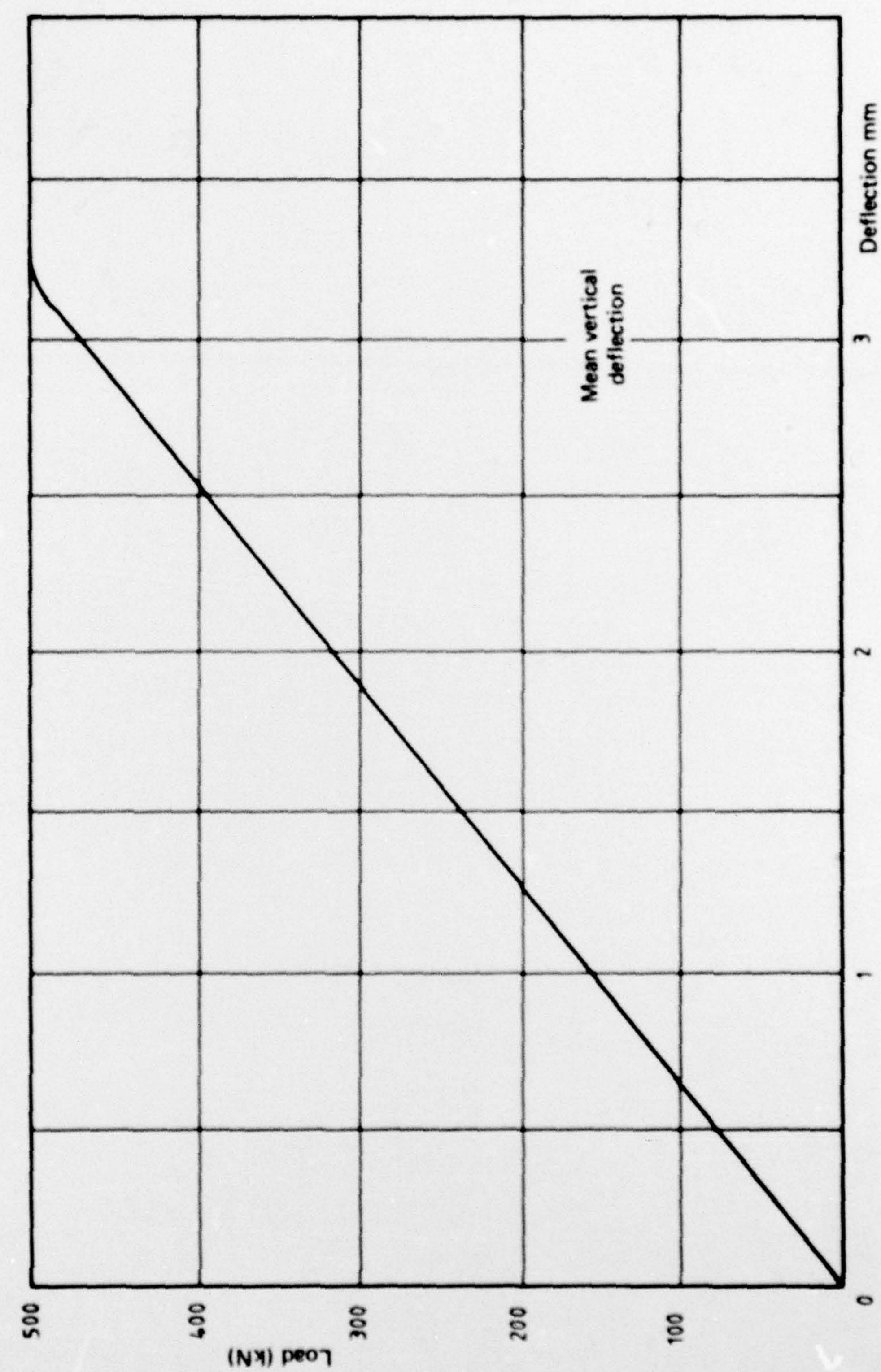



FIG. 6. LOAD vs DEFLECTION

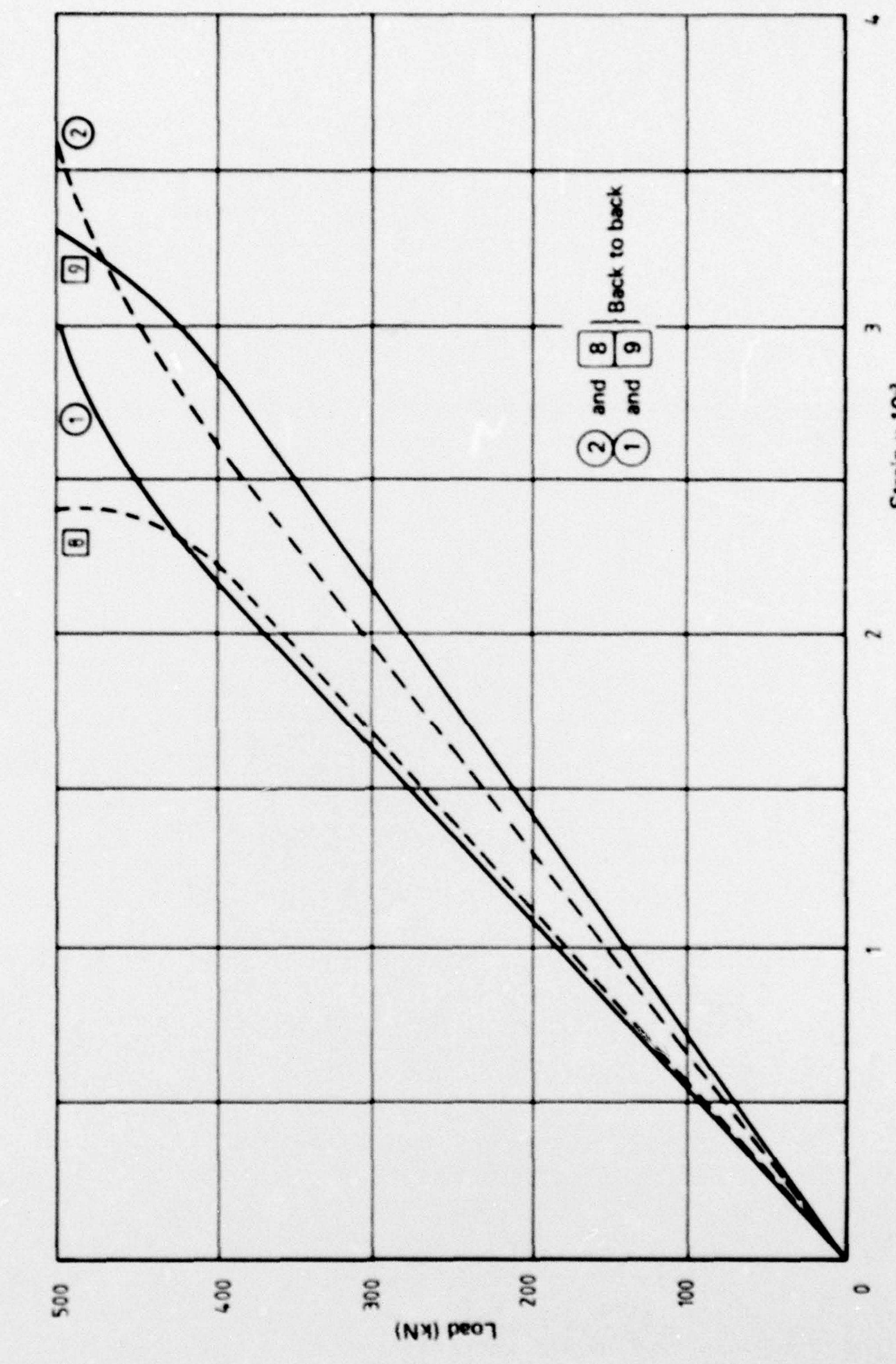



FIG. 7. LOAD vs STRAIN

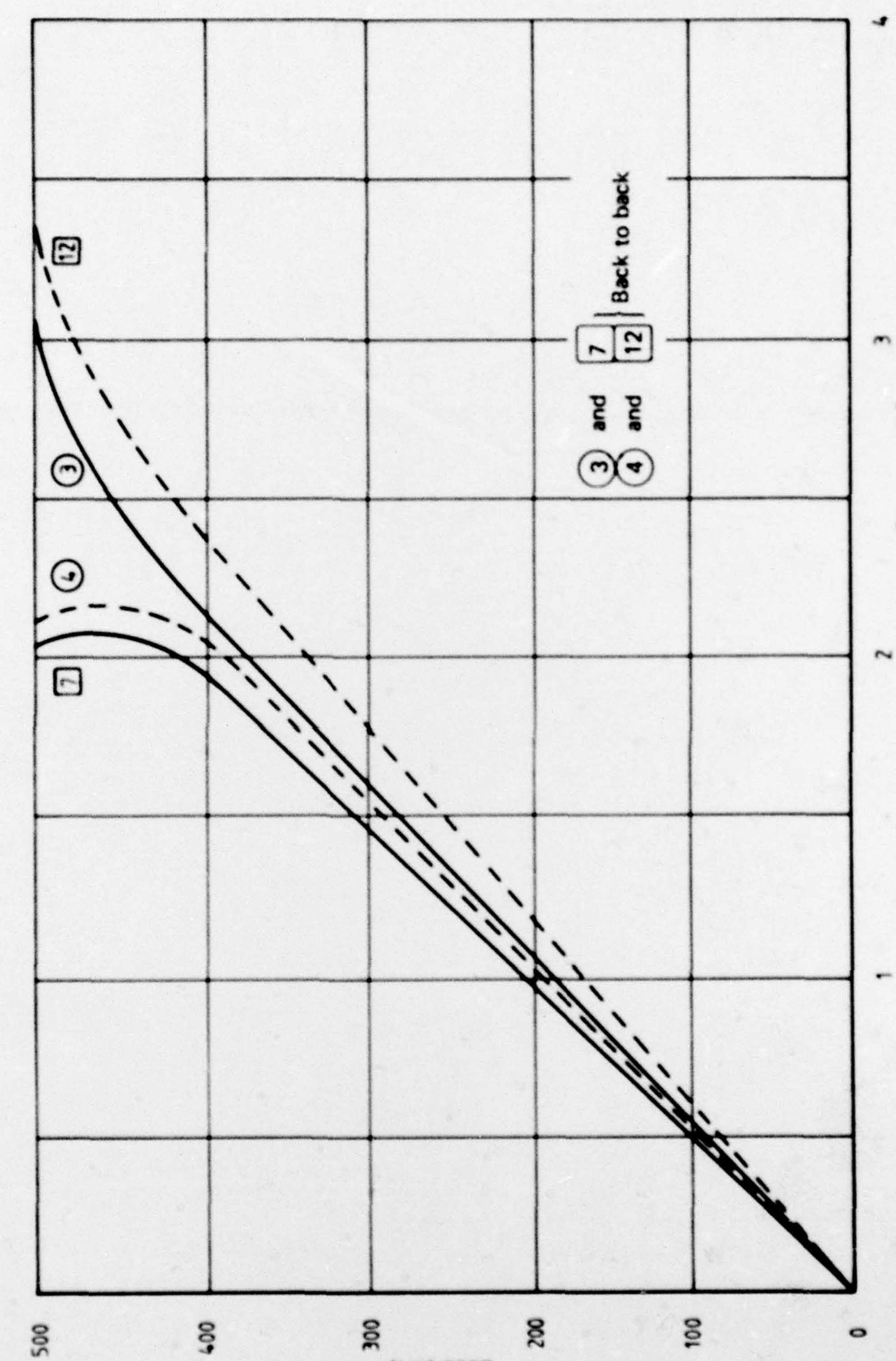



FIG. 8. LOAD vs STRAIN

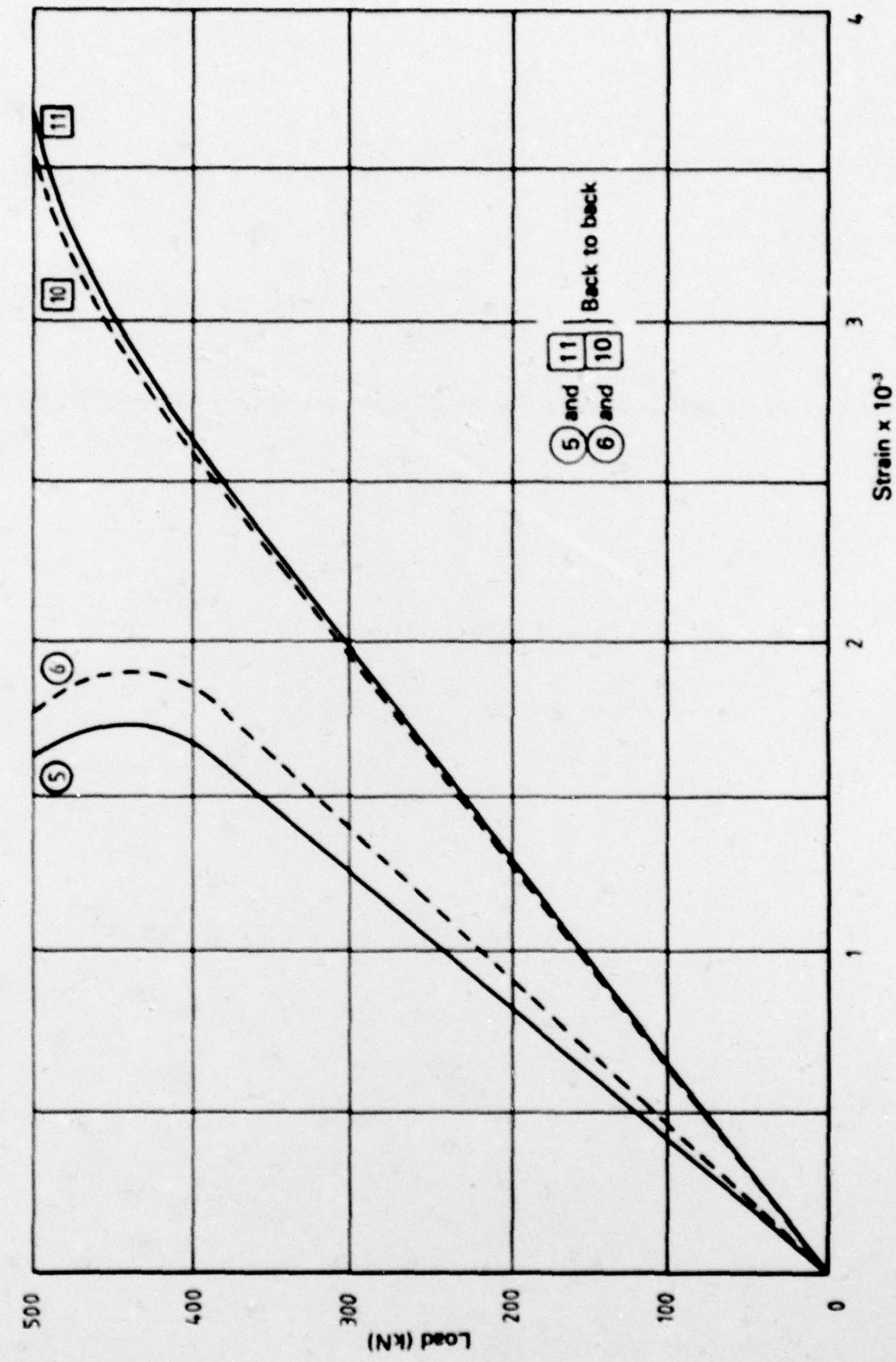



FIG. 9. LOAD vs STRAIN

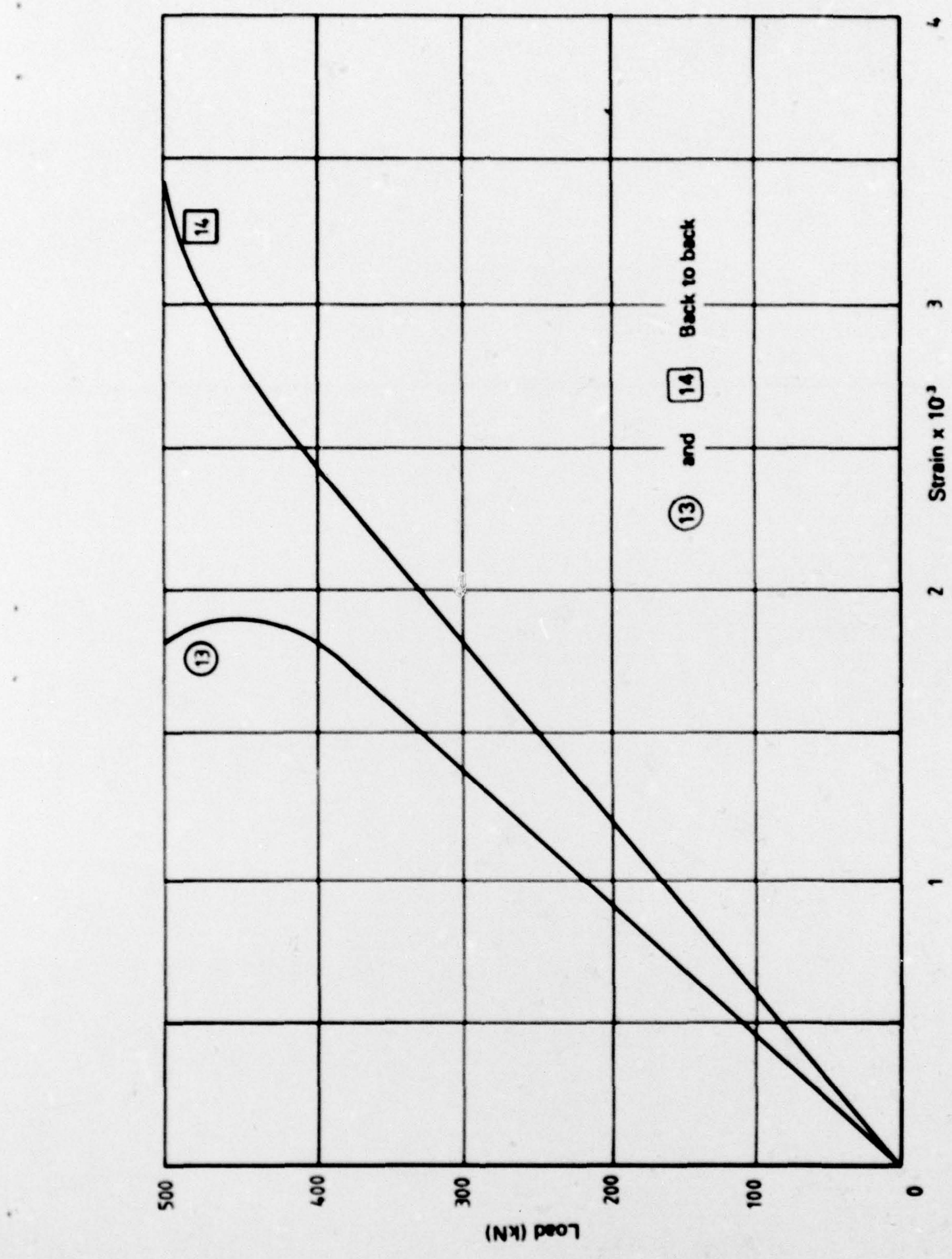


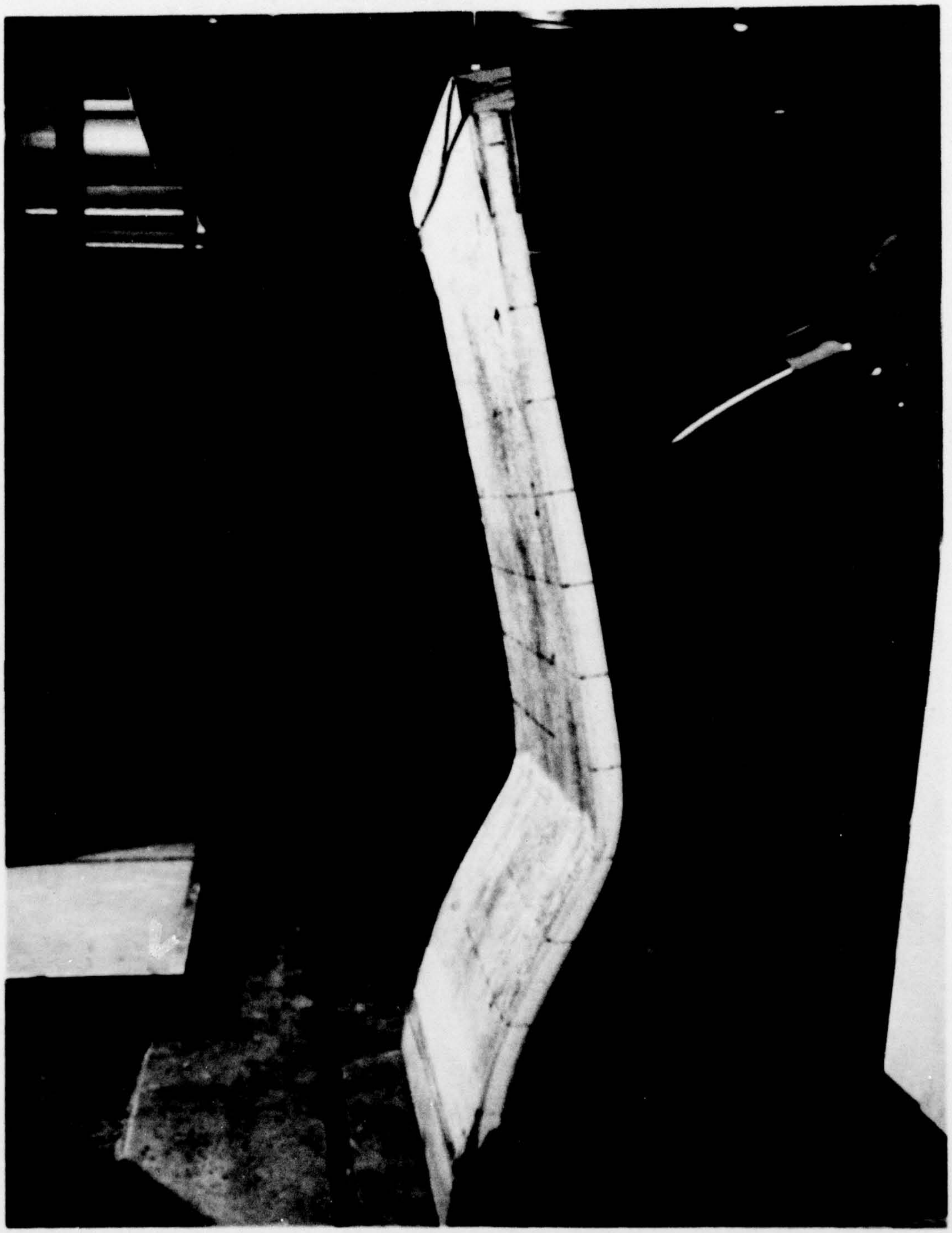

FIG. 10. LOAD vs STRAIN

Neg. No. 0454A

FIG. 11. PANEL AFTER RECOVERY FROM BUCKLING AND PRIOR TO GRP FAILURE TEST

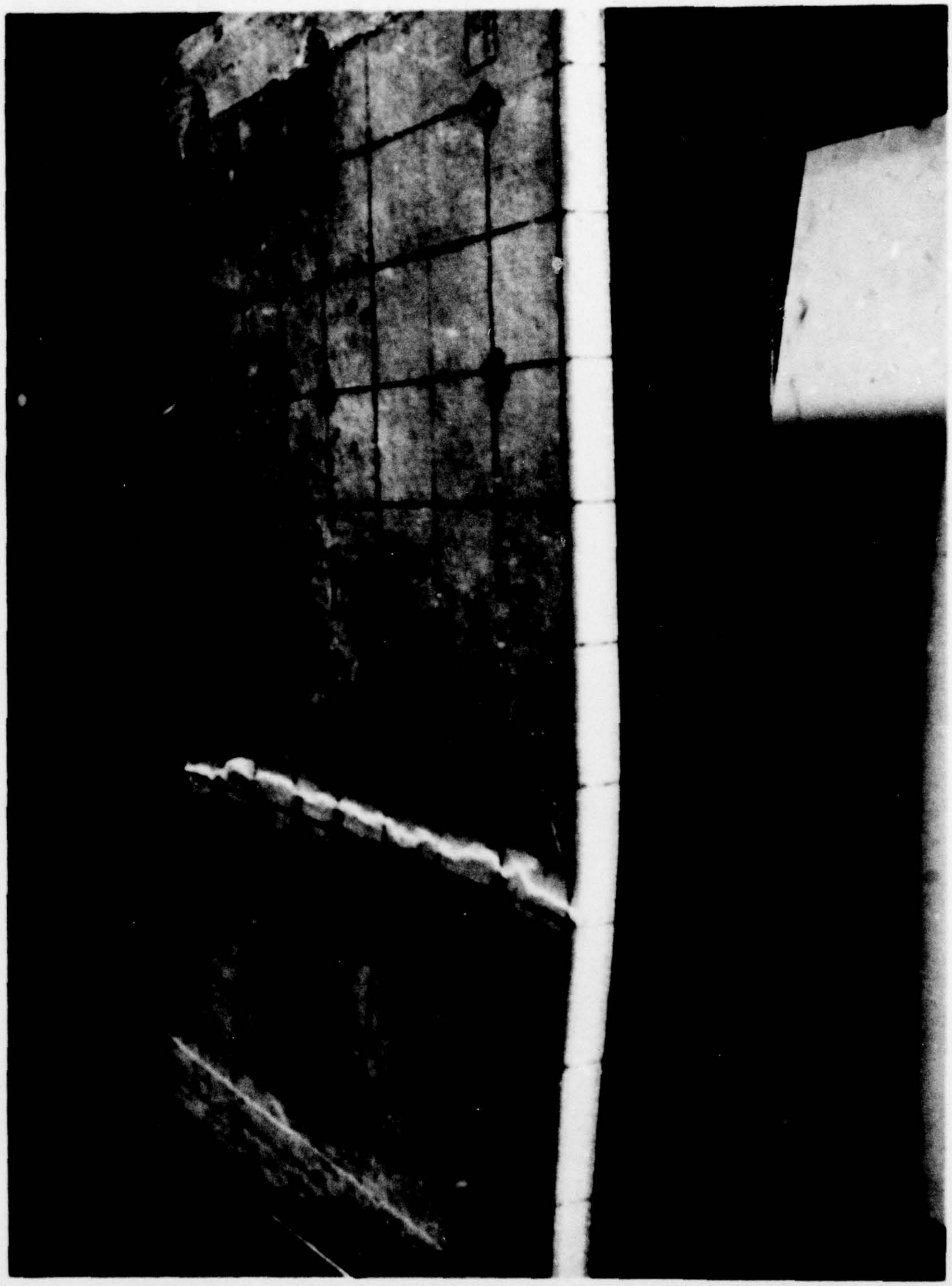
Neg. No. 0454F

FIG. 12. BUCKLED PANEL AT GRP FAILURE TENSION SIDE



Neg. No. 0454E

FIG. 13. BUCKLED PANEL AT GRP FAILURE COMPRESSION SIDE.



Neg. No. 0454G

FIG. 14. COMPRESSION FAILURE OF GRP (AFTER UNLOADING)

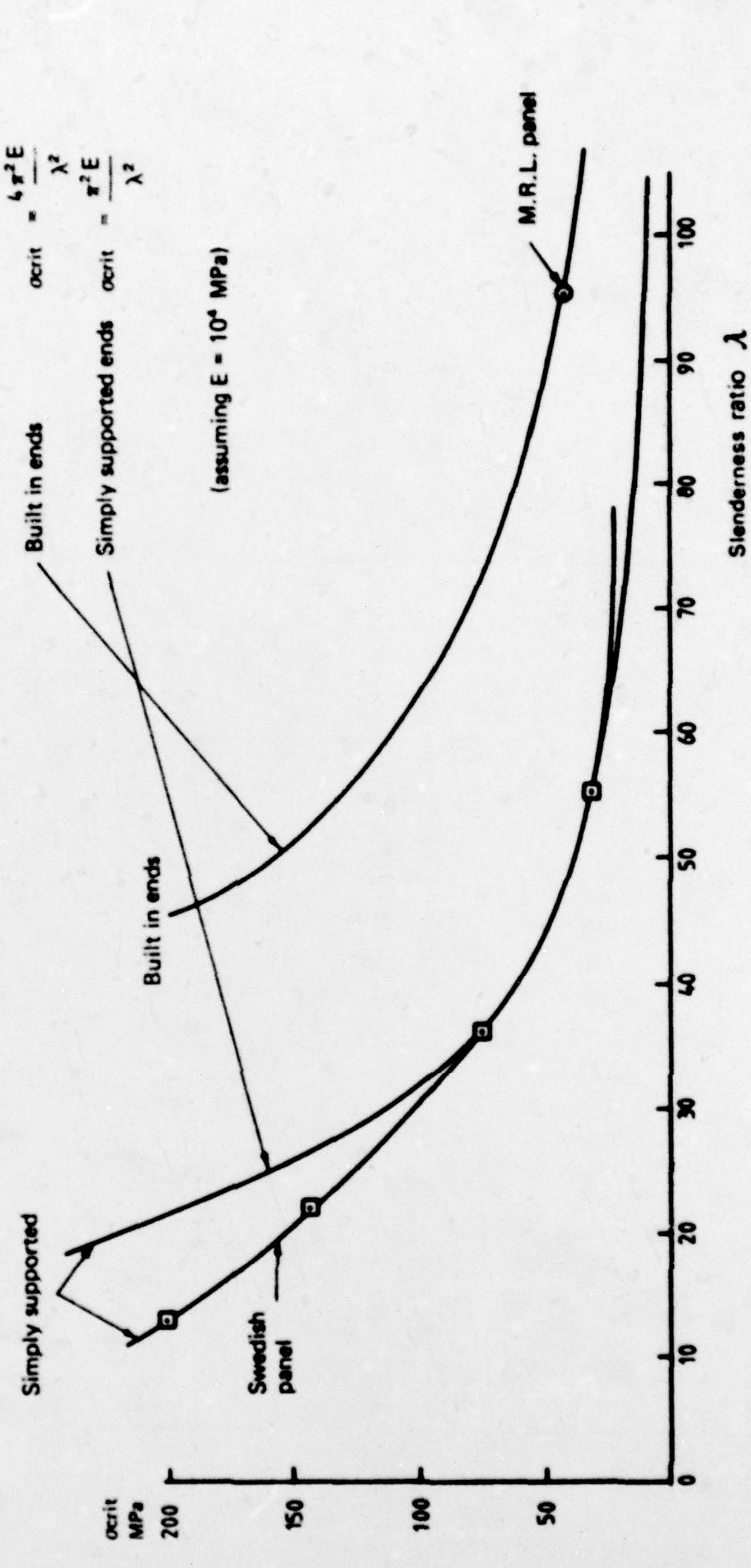



FIG. 15. BUCKLING STRENGTH OF SANDWICH PANELS

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No Limitation.

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Fibreglass reinforced plastics
Sandwich laminates
Chopped fibre composites
Reinforced Plastics
Tests
Compression tests
Buckling

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16. ABSTRACT:

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